14.1 - 14.4: Acids and Bases, pH

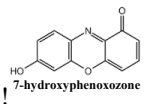
Acid Etched Glass

Properties of Acids and Bases

Physical:
Acids taste tart or sour: lemons, vinegar
Acids turn blue litmus* paper red (Demo)

Bases taste bitter and feel slippery: ever eaten soap?
Bases turn red litmus* paper blue (Demo)

* - Litmus is a pH sensitive compound historically extracted from lichens. First used in the 1300's, the chromophore (color sensitive compound) in litmus is 7-hydroxyphenoxozone.



7-hydroxyphenoxozone

Don't identify chemicals by taste or feel!
See Acid/Base Resource: 6

Properties of Acids and Bases

Both acids and bases are electrolytes: solutions which produce ions and conduct electricity.

Acids can react with metals to produce hydrogen gas and a metal salt.

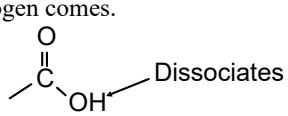
Demo: $Zn + HCl \rightarrow ZnCl_2 + H_2$

Acids react with carbonates to produce carbon dioxide, water, and a salt (ionic compound). Demo: Limestone ($CaCO_3$) + HCl.

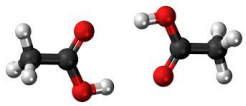
Acid Types

Most acids are oxyacids, containing the hydrogen ion plus an oxyanion, such as NO_3^- or ClO_2^-.

Organic acids are common, but weak, and have a carboxylate functional group, COOH, from which an ionizable hydrogen comes.



Demo - Class models acetic acid (dilute solution < 5% ionized).



Hydronium and Hydroxide Ions

Water hydrolyzes (breaks up) into hydroxide and hydrogen ions.
The hydrogen ions merge with water forming hydronium ions (H_3O^+).

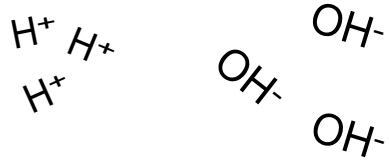
Hydronium ion
H_3O^+

In a neutral solution (pH = 7), these ions are equal.
In acids, (pH < 7) hydronium outnumbers hydroxide.
In bases (pH > 7) hydroxide outnumbers hydronium.

Arrhenius model of acids/bases

Svante Arrhenius in 1883 proposed a model that defined acids as substances that contain hydrogen atoms which ionize in water.

Bases contain hydroxide ions.



Brønsted-Lowry Model

Focuses on H^+ transfer: an acid is a H^+ donor; a base is a H^+ acceptor.

Example: HCl and water:

$$HCl + H_2O \longleftrightarrow H_3O^+ + Cl^-$$

Here, water is a base because it accepts the H^+ ion.

Conjugates

In accepting H^+, a base becomes a Conjugate Acid.

In giving up a H^+, an acid becomes a Conjugate Base.

Example: $HCl + H_2O \longleftrightarrow H_3O^+ + Cl^-$

Can give up hydrogen.

Can accept Hydrogen

From our example, on the product side, the hydronium can give up H^+, and the chloride can accept one.

1. Ammonia Example

Ammonia (NH_3) acts as a base in aqueous solution, because it absorbs a hydrogen from water, becoming the ammonium ion.

$$NH_3 + H_2O \longleftrightarrow NH_4^+ + OH^-$$

Which is the conjugate acid, and which is the conjugate base of this reaction?

Ammonia Answer

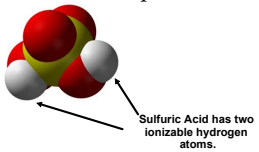
The different components can be paired up:
Acid – conjugate base pair: water - hydroxide ion.
Base – conjugate acid pair: ammonia - ammonium ion.

Base Acid Conjugate Acid Conjugate Base

$$NH_3 + H_2O \longleftrightarrow NH_4^+ + OH^-$$

Mono and Polyprotic acids

Monoprotic acids have one ionizable hydrogen ion.
Polyprotic – "many protons", such as:
Diprotic = two. Ex: sulfuric acid.
Triprotic = three. Ex: phosphoric acid.



2. Why is acetic acid (vinegar)(CH_3COOH) monoprotic?
- The H atoms connected to carbon don't dissociate.

Strengths of Acids/Bases

What makes an acid or base strong?

It's got nothing to do with whether it eats holes in things, or its concentration.

Strong acids or bases ionize completely in water and are good electrolytes; weak ones do/are not.

The short list of common strong acids are: sulfuric, nitric, hydrochloric, hydrobromic, hydroiodic, chloric ($HClO_3$), and perchloric ($HClO_4$) acids. See Resources Page 6.

Ion Product of Water

Water self-reacts to form a hydroxide ion (OH^-) and a hydronium ion (H_3O^+):

$$2\,H_2O \rightarrow OH^- + H_3O^+$$

The concentration of these ions in pure water is low: 1.0 E -7 M.

It is worth noting that the equilibrium expression for the self-ionization of water (at 25 °C) is:

$$K_w = [H^+][OH^-] = 1.0E-14$$

K_a - The Acid Constant

Depending on the degree of dissociation, weak acids can be sort of weak, or really weak.

Consider the following dissociated of hydrobromic acid in water at equilibrium:

$$HBr \rightleftharpoons H^+ + Br^-$$

The expression for this dissociation is:

$$K_a = \frac{[H^+][Br^-]}{[HBr]}$$

Note: while pure liquids and solids don't appear in equilibrium expressions, the presence of HBr indicates that it is in solution.

A table listing K_a values is on resource Page 7, and is used to find the pH of weak acid solutions.

pH

An expression of acidity:
Low pH = acidic, high pH = basic.

Mathematically:

$$pH = -\log[H^+]$$

$[H^+]$ = hydrogen ion concentration (M).

Desktop Calculator Tutorial:
Press the (-) button.
Press the LOG button.
Enter hydrogen ion concentration.

3. pH Example A

What is the pH of a 0.03 M solution of HCl?

Find the concentration of hydrogen ions first.

HCl breaks up in a 1:1 ratio, so a 0.03 M solution of HCl yields a 0.03 M concentration of H^+ and Cl^- ions.

$$pH = -\log[0.03] = 1.52$$

4. pH Example B

What is the pH of a 0.008 M solution of HNO_3?

Find the concentration of hydrogen ions first.

HNO_3 breaks up in a 1 : 1 ratio:
0.008 M HNO_3 yields a 0.008 M concentration of H^+ ions.

Answer

$$pH = -\log[0.008] = 2.09$$

pOH

Like pH, but looks at hydroxide ion concentration.

Mathematically:

$$pOH = -\log[OH^-]$$

$[OH^-]$ = hydroxide ion concentration (M).

For any aqueous solution:

pH + pOH = 14.00.

5. pOH Example

What is the pOH of the solution in Example 4?

The pH was 2.09.

$$pH + pOH = 14.00$$

$$pOH = 14.00 - 2.09 = \boxed{11.91}$$

Concentration

From pH or pOH, molar concentration is:

$$[H^+] = 10^{-pH} \quad \text{Or:} \quad [OH^-] = 10^{-pOH}$$

Desktop Calculator Tutorial:
Press [2nd], then the [LOG] button (10^x function).
Press the [(-)] button.
Enter pH (or pOH).

6. Molarity from pH Example

What is HNO_3 molarity if pH = 2.5 ?

$$[H^+] = 10^{-pH} = 10^{-2.5} = 0.0032\,M$$

Homework

Preview 14.5

14.1 - 14.4 Problems in your Booklet
Due: Next Class